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Human Centered Design Adaptation in Smart and Climate Resilient Public Spaces

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A B S T R A C T

Climate change and the digitalization of cities demand public spaces that are adaptive, inclusive, and user-oriented. This study aims to analyze the relationship between the application of human-centered design and thermal comfort, accessibility, safety perception, duration of use, and microclimate performance as an indication of climate resilience. The mixed methods method was used through behavioral observation, temperature and humidity measurements, questionnaires to 120 users, and interviews with eight stakeholders. Data were analyzed using descriptive statistics, Spearman correlation, and thematic analysis. The results show that vegetation, shade, adaptive furniture, universal access, and information technology are positively related to the quality of user experience. The research concludes that the integration of environmental performance, inclusive design, and user-oriented technologies supports the development of smart, climate-resilient public spaces

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INTRODUCTION

Urban public spaces are facing increasingly complex pressures due to increasing urban density, climate change, diverse social needs, and accelerating the adoption of digital technologies. Public spaces no longer only function as places of recreation and social interaction, but also as urban infrastructure that supports the health, comfort, safety, ecosystem services, and adaptive capacity of cities. Forczek-Brataniec and Jamioł (2024) affirm that streets, parks, and plazas have the potential to reduce the local impact of climate change through the utilization of ecosystem services and design that is responsive to environmental threats. At the same time, the application of Internet of Things technology in the development of smart cities allows for more responsive monitoring of environmental conditions and urban services. However, Ramadhan and Annisa (2024) show that the implementation of smart cities still faces challenges in terms of regulations, architecture, infrastructure readiness, and its connection to improving people's quality of life.

In the Indonesian context, the need for comfortable and climate-resilient public spaces is increasingly urgent because urban open spaces have to deal with increased temperatures, noise, air pollution, activity density, and land limitations. Research by Muladi et al. (2024) in Mataram City found a temperature difference of 0.83–1.07°C between green open space areas and non-green areas, which shows the role of vegetation in improving microclimate conditions. However, the quality of public space is not always even. Kurniati and Zamroni (2021) found that 14.89% of the public green open spaces studied in Yogyakarta are still in the uncomfortable category, especially related to circulation, cleanliness, security, lighting, and facilities for vulnerable groups. Shafira and Pramitasari (2024) also show that a number of public spaces have not paid adequate attention to the needs of children with physical disabilities and sustainability aspects. In addition, accessibility and availability of facilities have been proven to affect public interest in using public green open spaces in the Greater Jakarta area (Raniah, 2024).

The human-centered approach to design puts the user's needs, abilities, perceptions, behaviors, and experiences as the basis for design decision-making. In a smart public space, this approach is necessary so that technology is not only used to improve management efficiency, but also to strengthen inclusivity, accessibility, safety, and human well-being. Hasanuddin (2021) reminded that smart city development in Indonesia has the potential to become too technocratic and mechanistic when citizen participation is not placed as the main element. His research shows that the highest level of digital participation found is in the form of partnerships through hackathon activities in Jakarta, while several other participation channels are still at the level of consideration. Internationally, Almulhim and Aina (2025) also emphasized that the development of smart cities needs to move beyond technology orientation towards a framework that integrates human values, social needs, quality of life, and environmental sustainability.

Although research on public spaces, smart cities, and climate resilience continues to grow, previous studies have tended to address these three aspects separately. Santoso and Suwandono (2024), for example, evaluated the flexibility of benches, pedestrian paths, merchant facilities, and sanitation facilities in responding to changes in user behavior, but have not yet linked them to the performance of microclimates and smart technologies. Raniah (2024) focuses the analysis on the influence of accessibility and facilities on interest in the use of open space, while Muladi et al. (2024) focus more on measuring environmental services. At the international level, Zhu et al. (2025) found that the evaluation of public spaces from a user's perspective has covered multiple dimensions, but there is still fragmentation between subjective assessments of users and objective measurements of the environment. Meanwhile, an analysis of 114 projects from 29 countries by Forczek-Brataniec and Jamioł (2024) shows an increasing use of environmental mitigation, protection, recovery, reuse, and education strategies, but does not specifically explain the relationship between smart technologies, climate performance, and user experience in a single evaluation framework. Thus, there is a research gap in the form of the lack of an integrative model to assess the adaptation of human-centered design in public spaces that are at the same time intelligent, inclusive, and resilient to the climate.

Based on these gaps, this study aims to analyze the relationship between the application of human-centered design principles and the quality of smart public spaces in Bandar Lampung City. The analysis focused on five design elements, namely shading, vegetation, adaptive furniture, universal access, and information technology, as well as their relationship with thermal comfort, perceived accessibility, perception of security, activity patterns, and length of use of space. Climate resilience in this study was assessed indirectly through microclimate performance, shading ability, vegetation presence, drainage conditions, and sustainability of public space maintenance. The study used a mixed method based on post-occupancy evaluation that integrates physical measurements, user perception, behavioral observation, and stakeholder interviews.

Theoretically, this research is expected to produce a conceptual framework that connects human-centered design, smart public spaces, and climate resilience as three interdependent dimensions in architectural and urban design. The framework expands the evaluation of public spaces from physical and technological assessments to a multidimensional approach that includes thermal comfort, spatial behavior, universal accessibility, user perception, and environmental adaptability. Practically, the results of the research can be the basis for the preparation of design criteria for architects, urban planners, local governments, and public space managers in determining the placement of vegetation and shade, designing flexible furniture, providing inclusive access, and applying information technology that is relevant to the needs of users. This contribution is expected to support the formation of public spaces that are not only high-tech, but also comfortable, safe, inclusive, adaptive, and responsive to climate change.

LITERATURE REVIEW

Human-Centered Design in Public Space Design

Human-centered design is an approach that places human needs, abilities, behaviors, and experiences as the basis for design decision-making. In the context of smart cities, this approach is necessary to prevent public spaces from being developed solely based on technological sophistication or management efficiency. Ahmadzai (2025) explained that the application of human-centered design in the development of smart cities involves a divergent and convergent thinking process, namely the exploration of user needs broadly followed by the preparation of solutions according to the context. Orientation to users is also seen in the research of Hapsari et al. (2023), which assesses the effectiveness of urban parks based on comfort, safety, activities, and accessibility from the perspective of visitors. Thus, human-centered design adaptation needs to be implemented through need identification, behavioral observation, user experience evaluation, and repeated improvement of spatial elements.

Inclusivity and Universal Access in Public Spaces

Inclusivity refers to the ability of public spaces to be used safely, independently, and equally by people of different ages, physical abilities, and social backgrounds. Dwiputri (2024) found that the principle of inclusive design at Sidoarjo Square has not been fully implemented, especially in meeting the needs of people with disabilities and the elderly group. At the international level, Sádaba et al. (2024) place inclusivity as an important element in the framework of sustainable and resilient urban design. Based on these two studies, universal access is not enough to assess the existence of pedestrian paths or ramps, but must include the continuity of the path, ease of orientation, seating variation, lighting, readability of information, and safety of use. Assessments also need to consider the actual user experience, not just physical conformity to design standards.

User-Oriented Smart Technology

Technology in intelligent public spaces should serve as an instrument that supports the human experience, not as the end goal of design. Wang (2023) shows that the development of digital technologies can strengthen human-oriented urban design through spatial representation, public participation, and information management at various stages of design. Meanwhile, Ahmadzai (2025) emphasized the importance of an empathetic and participatory process so that smart city innovation remains in accordance with social issues and user needs. In this study, smart technology can be operationalized through information on environmental conditions, navigation systems, adaptive lighting, reporting media, and public information delivery. Its effectiveness needs to be assessed based on ease of use, readability, accessibility, reliability, user acceptance, and its contribution to the safety and comfort of the space.

Climate Resilience and Green Infrastructure

Climate resilience in public spaces is related to the ability of space to reduce the impact of heat, extreme rainfall, inundation, and environmental degradation while maintaining its social function. Sinatra et al. (2022) explain that the development of green open space as green infrastructure needs to be adapted to local characteristics through the principles of conservation, connectivity, and aesthetics. The approach shows that vegetation plays a role not only as a visual element, but also as part of an urban ecological system. Sádaba et al. (2024) also link spatial design at street level to increased inclusivity, social interaction, and urban resilience. Therefore, shading, vegetation cover, porous surfaces, rainwater management, and green network sustainability need to be seen as spatial strategies that support daily comfort as well as adaptability to climate change.

Thermal Comfort and Microclimate Performance

The thermal comfort of open spaces is influenced by the relationship between air temperature, humidity, wind speed, solar radiation, surface temperature, activity, and user perception. Safyan et al. (2024) evaluated the thermal comfort of the public space of Binjai Station using field measurements, the Predicted Mean Vote–Predicted Percentage of Dissatisfied index, and questionnaires of 178 respondents. Rahmadyani and Fahri (2024) also combined environmental condition data with user perception in assessing the thermal comfort of Taman Merdeka Square Pangkalpinang. Meanwhile, Tarigan et al. (2024) showed the importance of the density of green open space to air temperature, humidity, wind speed, and surface temperature in the street canyon area. The findings confirm that microclimate evaluation needs to combine objective measurements and subjective responses because measured thermal conditions are not necessarily felt equally by all users.

User Behavior, Adaptive Furniture, and Post-Occupancy Evaluation

The character of public spaces can change after use as people make adjustments based on habits, needs, and patterns of daily activities. Palupi and Rejeki (2024) found that the function of public open space in the Pekunden Flats has changed as a result of adaptation to residents' behavior. The study demonstrates the usefulness of post-residential evaluation to identify gaps between initial design and actual use. Hapsari et al. (2023) also showed that the effectiveness of public spaces is multidimensional because they are influenced by comfort, security, activities, and accessibility. In the context of this study, adaptive furniture needs to be assessed based on placement flexibility, anthropometric suitability, relationship with shading, support for individual and group activities, and its effect on duration of use. Behavioral observations, activity mapping, questionnaires, and interviews are needed to obtain a comprehensive picture of space use.

Human-Centered Design, Technology, and Climate Resilience Integration

Studies in Indonesia generally still assess thermal comfort, accessibility, user behavior, space effectiveness, or green infrastructure as separate aspects. International research has begun to link human-oriented approaches, digital technologies, inclusivity, and urban resilience, but most are still conceptual or address them at the city scale. This condition shows a gap in the form of limitations of empirical research that integrates microclimate performance, user experience, intelligent technology, universal access, and spatial behavior in a single evaluation of public space. This research positions the adaptation of human-centered design through five main elements, namely shading, vegetation, adaptive furniture, universal access, and information technology. These elements were analyzed in relation to thermal comfort, perception of safety, activity patterns, accessibility, and duration of use of space.

A mixed methods approach based on post-occupancy evaluation is suitable for testing such frameworks because it allows the incorporation of physical, behavioral, and perceptual data. Temperature and humidity measurements provided objective data on microclimate performance, while behavioral observations and questionnaires to 120 users provided information about activity patterns, comfort, safety, and duration of use. Interviews with 8 managers and designers were used to understand the management process, technology application, and design adaptation constraints. Quantitative data can be analyzed through descriptive statistics and correlation, while qualitative data is analyzed thematically. Since correlation analysis shows relationships and not direct causality, the interpretation of results needs to be focused on the interdependencies between variables and strengthened through qualitative data triangulation.

Based on the theoretical study and research gaps that have been identified, the conceptual framework of this research is presented in Figure 1. The framework describes the integration of quantitative and qualitative approaches in mixed methods research design to analyze the relationship between the application of human-centered design and the quality of climate-resilient smart public spaces.

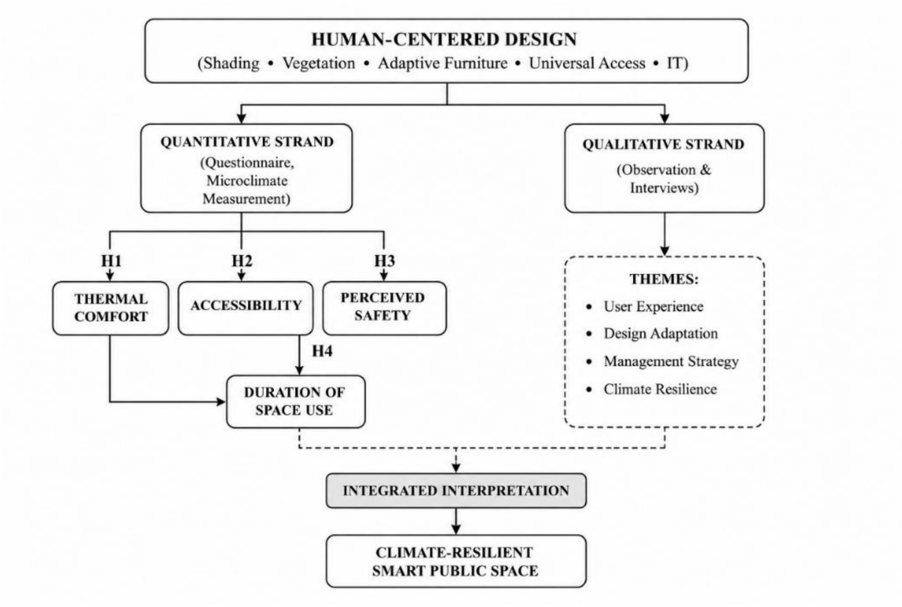

Figure 1. Conceptual Framework and Hypothesis Models of Mixed Methods Research

Based on Figure 1, a quantitative path was used to test the relationship between the application of human-centered design and thermal comfort, accessibility, security perception, and length of use of space through correlation analysis. Meanwhile, the qualitative path is carried out through behavioral observation and in-depth interviews to explore user experience, design adaptation, and public space management strategies. The results of the two approaches are then integrated to produce a more comprehensive understanding of the application of human-centered design in realizing intelligent public spaces that are adaptive, inclusive, and resilient to climate change.

Research Hypothesis

H1 : The application of human-centered design is positively related to thermal comfort in smart public spaces.

H2 : The application of human-centered design is positively related to accessibility in smart public spaces.

H3 :P The application of human-centered design is positively related to the perception of security in smart public spaces.

H4 : The application of human-centered design is positively related to the length of use of public space.

METHODOLOGY

Types of Research

This study uses a mixed methods approach with a convergent-parallel design in the framework of post-occupancy evaluation (POE) and cross-cutting case studies. Quantitative and qualitative data were collected over the same period, analyzed separately, then integrated to explain the relationship between the physical conditions of the space, technology, behavior, and user experience. The quantitative path examines the relationship between the application of human-centered design and thermal comfort, accessibility, perception of safety, and length of use of space. The qualitative track explores user experience, design adaptation, and public space management strategies. The POE was chosen because it allows evaluation of the performance of the space after use through surveys, observations, interviews, and physical measurements (Baharetha et al., 2025; Lolli et al., 2022; Ratnasari & Sudradjat, 2023).

Population and Sample

The research population includes all users of public spaces that are the location of the study in Bandar Lampung City during 2026. The quantitative sample consisted of 120 users selected using purposive intercept sampling. Respondents were at least 17 years old, had been on site for at least 15 minutes, used at least one public space facility, and were willing to participate in the study. Data collection was carried out on weekdays and weekends in the morning, noon, afternoon, and night periods.

The qualitative component involved eight purposively selected stakeholders, consisting of two public space managers, two architects, two urban planners, one maintenance officer, and one local government representative. Informants are selected based on their involvement and knowledge regarding the design, operation, maintenance, and development of public spaces in the City of Bandar Lampung (Khamid & Avivah, 2025; Nadella & Kusuma, 2024). (Khamid & Avivah, 2025; Nadella & Kusuma, 2024).

Research Instruments

The research instruments included a five-level Likert scale questionnaire, a physical audit sheet, a behavioral observation sheet, a digital thermo-hygrometer/data logger, a semi-structured interview guideline, and visual documentation. The questionnaire was used to measure users' perceptions of shading, vegetation, adaptive furniture, information technology, thermal comfort, accessibility, and safety. The duration of use is recorded in minutes through open-ended questions and confirmed through observation.

Universal access is assessed through a physical audit that includes lane continuity, ramp slope, elevation changes, surface conditions, directional markers, and connectivity to key facilities. Meanwhile, accessibility is measured based on user perceptions of the ease of reaching, entering, moving, and using public space facilities. The separation is done to avoid overlapping between the objective conditions of universal access and the subjective experience of the user.

The instrument items were adapted from indicators of urban comfort, space quality, user experience, and evaluation of public spaces developed by Kurniati and Fanani (2022), Nadella and Kusuma (2024), Khamid and Avivah (2025), and Sigilipu et al. (2023). The validity of the content was tested by three experts using Aiken's V with a limit of ≥0.80. The trial was conducted on 30 users outside the main sample, while the empirical validity and reliability used a point-total correlation of ≥0.30 and Cronbach's Alpha ≥0.70 (Yuliarto, 2021).

Data Collection Procedure

The research began with a literature review, the preparation of variables and hypotheses, the selection of locations, zone mapping, and instrument validation. Field data was collected through the distribution of questionnaires, temperature and humidity measurements, and behavioral observations in open, shaded, and vegetated zones. Measurements are carried out in conjunction with questionnaires so that microclimate conditions can be paired with user perceptions. Interviews were conducted with eight informants to obtain information on design adaptation, vegetation management, universal access, information technology, and climate resilience constraints. All data is then examined, anonymized, transcribed, and prepared for analysis.

Research Variables

Climate resilience is not placed as a stand-alone perception construct, but is assessed through environmental performance indicators and space management. These indicators include temperature and humidity differences between zones, availability of vegetation and shade, porous surface conditions, drainage function, the ability of the space to maintain activities in hot conditions or after rain, and continuity of facility maintenance. Therefore, the results of research on climate resilience are interpreted as an indication of the adaptive ability of public spaces, not as a measure of climate resilience as a whole.

Data Analysis Techniques

Quantitative data were analyzed using IBM SPSS Statistics through descriptive and correlation statistics. Pearson correlation is used when parametric assumptions are met, while Spearman correlation is used when the data is not normally distributed. The test was conducted at $\alpha=0.05$ to assess the relationship between the application of human-centered design and thermal comfort, accessibility, perception of safety, and length of use of space. Correlation analysis shows the relationship between variables, not the cause-and-effect relationship (Triadi, 2023).

Interview and observation data were analyzed thematically using NVivo through the stages of data introduction, coding, theme development, review, and interpretation (Byrne, 2022). Credibility is maintained through triangulation of sources and techniques. Quantitative and qualitative results were then integrated using joint displays to identify suitability, differences, and complementary relationships between findings.

RESEARCH RESULT

Characteristics of Respondents and Informants

A total of 120 questionnaires were declared complete and can be analyzed. Respondents consisted of 55 men (45.8%) and 65 women (54.2%). Based on age, the 17–25 year old group was the largest group, with 44 respondents (36.7%), followed by the 26–35 year old group with 35 respondents (29.2%), the 36–45 year old group with 24 respondents (20.0%), and the group over 45 years old with 17 respondents (14.2%). Data collection is carried out in a balanced manner on weekdays and weekends and covers the morning, afternoon, evening, and night periods.

The qualitative component involved eight informants, consisting of two public space managers, two architects, two urban planners, one maintenance officer, and one local government representative. The informant codes used include PG for managers, AR for architects, PR for planners, PM for maintenance officers, and PD for local governments.

Table 1. Characteristics of respondents

Features	Category	Quantity	Percentage
Gender	Male	55	45,8%
	Women	65	54,2%
Age	17–25 years old	44	36,7%
	26–35 years old	35	29,2%
	36–45 years old	24	20,0%
	>45 years old	17	14,2%
Type of day	Weekdays	60	50,0%
	Weekends	60	50,0%
Observation time	Morning	30	25,0%
	Afternoon	30	25,0%
	Sore	30	25,0%
	Night	30	25,0%

Results of Instrument Validity and Reliability

An assessment of the validity of the content by three experts resulted in an Aiken's V value between 0.84 and 0.96. All items meet the minimum acceptance limit of 0.80. Trials of 30 users outside the main sample resulted in a corrected point-total correlation value between 0.41 and 0.81. The value of Cronbach's Alpha for each construct is between 0.78 and 0.86 so that all instruments are declared reliable.

Table 2. Empirical validity and construct reliability

Construct	Number of items	Item-total correlation	Cronbach's Alpha
Shading	4	0,47–0,76	0,82
Vegetasi	4	0,44–0,74	0,80
Adaptive furniture	4	0,41–0,71	0,78
Universal access	5	0,46–0,79	0,85
Information technology	4	0,42–0,73	0,79
Thermal comfort	4	0,50–0,81	0,86
Security perception	4	0,45–0,77	0,83

Microclimatic Conditions of Public Spaces

Measurements show that there is a difference in temperature and humidity between open zones, flooded zones, and vegetated zones. The open zone has the highest average air temperature of 31.65°C, while the shaded zone has an average temperature of 29.98°C and the vegetated zone 29.43°C. The average temperature difference between open zones and vegetated zones reaches 2.22°C.

The biggest difference was found during the day. The average temperature of the open zone reached 34.6°C, while the sheltered zone was recorded at 31.8°C and the vegetated zone was 30.9°C. In this period, the vegetated zone had a temperature 3.7°C lower than the open zone. The relative humidity in the vegetated zone was also higher throughout the measurement period.

Table 3. Temperature and humidity by zone

Period of project	Open zone	Sheltered Zones	Bervegetasi area
Morning	29,7°C; RH 70%	28,8°C; RH 73%	28,4°C; RH 75%
Afternoon	34,6°C; RH 55%	31,8°C; RH 61%	30,9°C; RH 65%
Sore	32,8°C; RH 61%	30,4°C; RH 67%	29,8°C; RH 70%
Night	29,5°C; RH 72%	28,9°C; RH 75%	28,6°C; RH 77%
Average temperature	31,65°C	29,98°C	29,43°C

Assessment of Human-Centered Design Elements

Vegetation obtained the highest average score of 4.15, followed by shade of 4.08. Adaptive furniture received a score of 3.72, universal access 3.61, and information technology 3.58. The overall score of the *human-centered design application* was 3.83 with a standard deviation of 0.55.

In the outcome variables, thermal comfort obtained an average score of 3.89, safety perception 3.86, and accessibility 3.70. A total of 82 respondents (68.3%) stated that they were comfortable or very comfortable in zones that have a combination of vegetation and shade. In the open zone, the proportion of respondents who gave a similar assessment only reached 34.2%.

Table 4. Descriptive statistics of research variables

Variabel	Average	Default deviation	Category
Shading	4,08	0,62	Height
Vegetasi	4,15	0,58	Height
Adaptive furniture	3,72	0,70	Height
Universal access	3,61	0,74	Height
Information technology	3,58	0,77	Height
Overall *human-centered design*	3,83	0,55	Height
Thermal comfort	3,89	0,64	Height
Accessibility	3,70	0,71	Height
Security perception	3,86	0,66	Height

Activity Patterns and Length of Space Use

Behavioral observations were conducted in 16 sessions and resulted in 1,036 activity events. Sitting activities and social interaction were the most activities, with 398 incidents (38.4%). Running activities were recorded as many as 288 incidents (27.8%), waiting or resting activities as many as 192 incidents (18.5%), the use of technology or information media as many as 79 incidents (7.6%), and other activities as many as 79 incidents (7.7%).

A total of 640 activity events (61.8%) took place in zones that had vegetation, shade, or a combination of both. During the day, 74.5% of sedentary activities, such as sitting, talking, reading, and waiting, are concentrated in shaded and vegetated zones.

Table 5. User activity distribution

Activity type	Frequency	Percentage
Sitting and social interaction	398	38,4%
Walk	288	27,8%
Waiting or resting	192	18,5%
Using technology/information	79	7,6%
Other activities	79	7,7%
Total	1.036	100%

The length of time used in the space ranges between 18 and 145 minutes, with an average of 62.8 minutes. Open zone users have an average duration of 38.6 minutes, shaded zone users 64.2 minutes, and vegetation zone users 71.5 minutes.

Table 6. Length of use based on zone characters

Main use zones	Average duration	Default deviation
Open zone	38.6 minutes	17,8
Sheltered Zones	64.2 min	22,5
Bervegetasi area	71.5 minutes	25,1

Hypothesis Testing Results

The results of the distribution examination show that some constructs do not meet the assumption of normality. Therefore, hypothesis testing was carried out using Spearman correlation at a significance level of 0.05.

The application *of human-centered design* had a positive and significant relationship with thermal comfort of 0.64. The relationship with accessibility obtained a coefficient of 0.59, the relationship with the perception of security was 0.53, and the relationship with the length of time of use of space was 0.47. The entire significance value is below 0.001. Thus, H1, H2, H3, and H4 are supported by research data.

Table 7. Hypothesis test results

Hipotesis	**Variable relationships**	**Coeficin**	**Value p**	**Verdict**
H1	HCD–thermal comfort	0,64	<0.001	Supported
H2	HCD–accessibility	0,59	<0.001	Supported
H3	HCD–security perception	0,53	<0.001	Supported
H4	HCD–length of use	0,47	<0.001	Supported

Analysis of each element showed that vegetation had the strongest relationship with thermal comfort of 0.62. Shading has a relationship of 0.58 with thermal comfort. Adaptive furniture was associated with 0.49 years of use, universal access was associated with accessibility by 0.66, and information technology was associated with security perception by 0.41.

Table 8. Correlation of design elements to yield variables

Design elements	**Outcome variables**	**Coeficin**	**Value p**
Vegetasi	Thermal comfort	0,62	<0.001
Shading	Thermal comfort	0,58	<0.001
Adaptive furniture	Length of use	0,49	<0.001
Universal access	Accessibility	0,66	<0.001
Information technology	Security perception	0,41	<0.001

Air temperature had a negative relationship with thermal comfort of −0.57 with a $p<0.001$ value. The higher the air temperature in the use zone, the lower the respondent's thermal comfort rating.

Qualitative Results: Shading and Vegetation

The first theme shows that shading and vegetation are seen as the elements that most directly affect the user's comfort. All informants mentioned that areas with shade trees and shade structures have a higher intensity of use, especially during the day and evening.

"*Visitors always look for a location under a tree or canopy first. When the shade area is full, most of it just passes by and doesn't settle in the open space*." (PG1, interview, April 14, 2026)

"*Vegetation is not just a visual element. The temperature difference is evident when users move from the open plaza to the area with a tight treetop*." (AR1, interview, April 17, 2026)

These results are consistent with temperature measurements that show that the vegetated zone has the lowest average temperature and the longest duration of use.

Qualitative Results: Adaptive Furniture and Activity Patterns

Six out of eight informants stated that furniture that can support individual and group activities increases the flexibility of space use. Seating under shade is used for longer than furniture in the open zone.

"*The benches under the auspices are almost always filled. Users also often shift their sitting positions or gather around benches to adjust to group needs*." (PG2, interview, April 21, 2026)

"*Furniture needs to be flexible, but still have security. Furniture that is too permanent has a hard time adjusting to activity, while loose furniture has a risk of being moved or damaged*." (AR2, interview, April 23, 2026)

Observations show that social activities and waiting are more likely to take place around furniture that is in the flooded zone. These qualitative findings are in line with the positive correlation between adaptive furniture and length of use of space.

Qualitative Outcome: Universal Access

Seven informants mentioned that universal access has not been implemented evenly. Key issues include disconnected lanes, elevation changes, non-uniform surfaces, limited directional markers, and indirect connections between access lanes, seating areas, and sanitation facilities.

"*Some paths are actually wheelchair accessible, but the connection is cut off when heading to the seating area and toilets. Users will eventually have to take longer routes*." (PR1, interview, April 28, 2026)

"*The problem is not only the existence of the ramp, but the continuity of the path from the entry point to the main facility. In some parts, the difference in surface is still an obstacle*." (PR2, interview, April 30, 2026)

The results of observations showed that elderly users and users with reduced mobility were more likely to choose a path with a flat surface despite having a longer distance. These findings correspond to the strong relationship between universal access and perceived accessibility.

Qualitative Results: Information Technology and Security Perception

Six informants assessed that information technology in the public space still functions mainly as a means of conveying public information. Information on temperature conditions, air quality, accessible navigation, facility availability, and damage reporting is not yet integrated into a single system.

"*The available technology is still limited to information boards and several lighting points. The direct environmental information is not yet accessible to users*." (PD1, interview, May 5, 2026)

"*The lighting is quite conducive to a sense of security, but some points are covered in vegetation and have not been connected to a responsive monitoring system*." (PG1, follow-up interview, May 7, 2026)

Observation data shows that the use of digital information media only covers 7.6% of all activities. Although information technology has a positive relationship with the perception of security, the strength of the relationship is lower than the relationship between vegetation and shade and thermal comfort.

Qualitative Outcomes: Climate Sustainability and Sustainability

Seven informants identified maintenance as the main factor that determines the sustainability of public space performance. The problems found include budget limitations, vegetation maintenance, drainage channels, furniture damage, and coordination between management units.

"*Good design doesn't always last when it's not routine maintenance. Trees, drainage, lights, and furniture should be inspected as a single system*." (PM1, interview, May 12, 2026)

"*Climate resilience is not enough to be achieved by adding vegetation. Drainage systems, surface materials, shade, and maintenance patterns must be planned in an integrated* manner." (AR1, follow-up interview, May 15, 2026)

The informant also mentioned that damage to the drainage system and reduced quality of vegetation directly affect the ability of the space to maintain comfort after rain and during hot periods.

Integration of Quantitative and Qualitative Results

Data integration showed the compatibility between the results of microclimate measurements, questionnaires, behavioral observations, and interviews. Vegetated zones have the lowest average temperature, higher comfort scores, greater concentrations of sedentary activity, and the highest length of use. All informants also placed vegetation and shade as the top priority for design adaptation.

In the furniture aspect, the positive correlation with the length of use is supported by observation results that show the concentration of social activities around the bench. Interviews show that the flexibility of furniture increases the variety of activities, although it poses an additional need for supervision and maintenance.

Lower universal access scores compared to vegetation and shade are consistent with the findings of disconnected paths and the selection of alternative routes by users. The interview data reinforces these results by showing that accessibility is influenced by the continuity of travel, not just the existence of individual facilities.

Information technology obtained the lowest average score among the five design elements. Observational data showed a limited level of use of digital facilities, while interviews showed that environmental information, navigation, lighting, and reporting mechanisms had not been integrated.

Table 9. Integration of *mixed methods findings*

Aspects	**Quantitative results**	**Results of observations and interviews**	**Integrations**
Shading and vegetation	Scores of 4.08 and 4.15; correlation with convenience 0.58 and 0.62	Sedentary activity is concentrated in shady areas; Prioritized by all informants	Mutually reinforcing findings
Adaptive furniture	Score 3.72; correlation with length of use 0.49	Shaded furniture is more often used for social activities	Complementary findings
Universal access	Score 3.61; correlation with accessibility 0.66	Found disconnected lanes and alternative route selection	Mutually reinforcing findings
Information technology	Score 3.58; correlation with safety 0.41	Limited digital usage and unintegrated systems	Mutually reinforcing findings
Thermal comfort	Score 3.89; Temperature correlation −0.57	Users settle longer in cooler zones	Mutually reinforcing findings

Differentiating Findings

The data show that physical-ecological elements, especially vegetation and shade, have a stronger relationship with user experience than information technology. Vegetation and shade obtained the highest scores and showed a strong association with thermal comfort, while information technology obtained the lowest scores and a weaker association with the perception of security.

These findings differ from the trend of smart city studies that place digital technology as the dominant component. In the results of this study, technology has not yet become the main element that determines the length of use and thermal comfort. The integration of new technologies is seen in the information and security aspects, while environmental performance and usage patterns are more related to vegetation, shade, furniture, and accessibility.

Overall, quantitative and qualitative results show that the application of *human-centered design* is positively related to thermal comfort, accessibility, perception of safety, and length of use of public spaces. The alignment between physical measurements, user perceptions, behavioral patterns, and informant experiences suggests that climate-resilient, intelligent public spaces require the integration of ecological, spatial, social, and technological elements.

DISCUSSION

The results showed that the application of human-centered design was positively related to thermal comfort, accessibility, security perception, and length of use of public spaces. The strongest relationship was found in thermal comfort (rs = 0.64), followed by accessibility (rs = 0.59), perception of safety (rs = 0.53), and length of use (rs = 0.47). The pattern shows that the quality of public spaces is not only determined by the existence of facilities, but by the ability of physical, ecological, and technological elements to respond to the actual needs of users. These quantitative findings are strengthened by the results of observations and interviews that show the concentration of sedentary activities in shaded and vegetated areas, route selection based on ease of access, and the tendency of users to stay longer in comfortable zones.

Vegetation and shading are the most dominant elements in the formation of thermal comfort. The vegetated zone has an average temperature of 2.22°C lower than the open zone, while during the day the difference reaches 3.7°C. A negative relationship between air temperature and thermal comfort (rs=−0.57) showed that a decrease in heat exposure was directly related to an increase in comfort perception. These findings are in line with Milantara et al. (2024), who showed the function of trees in improving the microclimate of pedestrian paths, and Tarigan et al. (2024), who found that areas with a higher density of green open space have better thermal conditions than areas with low vegetation. The results also support Safyan et al. (2024), who affirm the importance of combining environmental measurements and user perception because thermal comfort is an adaptive response to the physical conditions of the space.

Higher use times in vegetated and shaded zones indicate that microclimatic performance influences spatial behavior. The average duration of use of the vegetated zone reaches 71.5 minutes, while the open zone is only 38.6 minutes. Adaptive furniture was also positively associated with length of use (rs=0.49), especially when placed in an area protected from heat. These findings show that furniture does not work as a single element, but depends on location, shade, orientation, and its ability to support individual or group activities. These results support Santoso and Suwandono (2024), who emphasize the need for flexible design so that elements of public spaces are able to adapt to changes in user behavior. Thus, the adaptation of public spaces needs to be carried out through an integrated configuration of vegetation, shade, furniture, and activity patterns, not just an increase in the number of benches or facilities.

A strong relationship between universal access and perceived accessibility (rs = 0.66) suggests that travel continuity is an important part of the user experience. Interview findings regarding disconnected paths, elevation changes, non-uniform surfaces, and limited relationships between entrances, seating, and sanitation facilities explain why universal access scores are lower than vegetation and shade. These results are in line with Dwiputri (2024), who found that the application of inclusive design in public spaces has not fully accommodated groups of people with disabilities and the elderly. Raniah (2024) also shows that accessibility and availability of facilities affect public interest in using public green open spaces. This means that universal access must be understood as a complete, secure, readable, and autonomously usable travel system, not just as the existence of a separate ramp or dedicated lane.

Information technology scored lowest among the five elements of human-centered design and had a weaker relationship with security perceptions (rs=0.41). This does not mean that technology is not important, but it does show that the function of technology in the research site has not been integrated with the needs of users. Technology is still dominant in the form of information boards and lighting, while microclimate information, accessible navigation, reporting mechanisms, and monitoring of facility conditions are not yet available in an integrated manner. This finding corroborates Hasanuddin's (2021) criticism that the implementation of smart cities can become technocratic if technology is not accompanied by participation and orientation to citizens. Almulhim and Aina (2025) also emphasized that the development of smart cities needs to shift from technological orientation to quality of life, social inclusion, and human needs. Consequently, technology in public spaces should serve as a support for decisions and user experience, not just a symbol of modernization.

Conceptually, the results show that the climate resilience of public spaces is formed through the relationship between environmental performance, spatial flexibility, inclusivity, technology, and maintenance capacity. The findings on the importance of vegetation, drainage, furniture, and lighting care show that resilience is not completed at the design stage. Forczek-Brataniec and Jamioł (2024) place public spaces as infrastructure that can help cities cope with the local impacts of climate change, while Sádaba et al. (2024) link street-level design with urban sustainability, inclusivity, and resilience. The results of this study expand on both views by showing that the effectiveness of resilience strategies needs to be evaluated based on user experience and behavioral patterns after space is used.

These findings also fill in the gaps in previous research that tend to separate microclimate evaluation, accessibility, user behavior, and technology application. The study integrated temperature and humidity measurements, perceptions of 120 users, behavioral observations, and interviews of eight stakeholders within the framework of the POE. This approach shows that the assessment of public space from the perspective of the user needs to be read alongside the physical data of the environment. However, the dominance of young age respondents, the use of non-probability samples, and observations in a single urban context limit the generalization of results. Latitude cut design and correlation analysis also cannot ensure cause-effect relationships.

Follow-up research needs to use a probability sample that includes a larger proportion of elderly, child, and disabled users and compare multiple public spaces with different characters. Microclimate measurements should include wind speed, average radiation temperature, surface temperature, solar intensity, and PET or UTCI index. Longitudinal observations in the rainy and dry seasons are required to assess the consistency of space performance. Subsequent research can also use regression modeling or structural equation modeling to test the direct and indirect relationship between design elements, comfort, safety, accessibility, and length of use. Technology evaluation should be carried out through prototypes and user participation so that the innovations implemented really improve the quality of public spaces.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that the application of human-centered design is positively and significantly related to thermal comfort, accessibility, security perception, and length of use of public space in Bandar Lampung City. The strongest relationship was found in thermal comfort (rs = 0.64), followed by accessibility (rs = 0.59), perception of safety (rs = 0.53), and length of time of use of space (rs = 0.47). Vegetation and shade are the most dominant elements because the vegetated zone has an average temperature 2.22°C lower than the open zone and shows the longest duration of use. The integration of quantitative and qualitative results also shows that adaptive furniture supports social activities, the continuity of universal access determines ease of use, while information technology is not fully integrated with the needs of users and space management.

The development of smart and climate-resilient public spaces needs to prioritize equitable distribution of vegetation and shade, the placement of adaptive furniture in comfort zones, the continuity of universal access points, and the integration of technology for microclimate information, navigation, lighting, and facility reporting. Local governments and managers also need to implement integrated maintenance of vegetation, drainage, furniture, lighting, and technological devices. Because the study uses a non-probability sample, cross-sectional design, and a single-city context, the results need to be applied carefully and adjusted to the environmental, social, and governance character of each public space.

ADVANCED RESEARCH

Further research is recommended using longitudinal design and comparative studies in several public spaces by involving children, the elderly, and people with disabilities in a more proportional manner. Measurements can be extended to wind speed, surface temperature, solar radiation, PET or UTCI, as well as Internet of Things-based environmental sensors. Regression analysis, structural equation modeling, and microclimate simulations can also be used to test the direct or indirect relationship between design, environmental performance, technology, behavior, and user experience.

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